Medical Imaging in small animal orthopaedics

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Introduction

The history of musculoskeletal imaging began with Roentgen's discovery of X-rays in 1895. Plain radiography has since become the initial, and in many cases, the only imaging modality for the diagnosis and follow up of orthopaedic disease. A wide range of imaging options is now available but the "perfect" imaging protocol does not exist because imaging parameters will be both patient and disease specific. Economic considerations will also have to be taken into account. When assessing image quality, one must consider both contrast resolution and spatial resolution. Contrast resolution refers to the ability to distinguish different normal tissues and normal from abnormal tissue. Spatial resolution refers to the ability to depict and distinguish small objects that are in close proximity.

In humans, musculoskeletal imaging applying arthrography, scintigraphy, computerised tomography (CT), magnetic resonance imaging (MRI), ultrasound (US) and arthroscopy is used on a daily basis. In veterinary orthopaedics, plain radiography was the routine imaging technique for diagnostic purposes and follow up for decades, and is still routinely used in common practice. However, more and more, the veterinary profession gets access to more sophisticated technology like CT and MRI. There are nowadays several practices in France, Germany and Austria using these imaging techniques. Also ultrasound and arthroscopy have moved into the interest of orthopaedic surgeons for diagnoses of several joint diseases and have become a routine procedure in several orthopaedic clinics. All these imaging techniques have their merits but also their limits.

Radiography, ultrasonography, scintigraphy CT or MRI may be used alone or in any combination. The protocol finally selected will depend on the history, clinical findings and the questions that should be addressed by the examination. Other important criteria include the strengths and limitations of the modality in question, of course whether or not the modality is available on site, radiation hazards and other safety issues, and the costs (cost - benefit) involved.

Typical imaging algorithm for orthopaedic cases

a) Conventional X-ray with radiographic signs that are typical for a specific diagnosis (e.g. flattening of humeral head for OCD). Other imaging procedures are not required or indicated.

b) An examination with equivocal findings (e.g. irregular borders and radiolucency of supraglenoid tubercle) for DDx "trauma" and "neoplasia". Additional imaging procedures (e.g. Ultrasound) are indicated. Often, a sequence of 2 or more diagnostic modalities is necessary to eliminate differential diagnosis from the initial list and to establish the correct diagnosis.

Imaging modalities available for veterinary orthopaedics

Technique	Benefit	Specific use	Limitations
Scintigraphy	High sensitivity for early/active disease and for surveying the entire skeleton.	Localising the site of obscure lameness. The cause may be inconclusive. Investigation of the metabolic function of the skeleton.	Poor spatial resolution and conclusive interpretation of findings.
Radiography	Good for bony structures. Excellent spatial resolution. Some indirect information on soft tissues.	Evaluation of the subchondral bone plate, trabecular subchondral bone, articular margins, and peri-capsular attachments.	Generally poor for soft tissue changes. Superimposition of structures.
Stress radiography	Indirect method for diagnosis of ligamentous problems.	Very sensitive for detection of ruptured cranial cruciate ligament	Radiation safety needs to be addressed.
Arthrography	Simple to use. Mostly used in the shoulder joint. Gives some information regarding intra-articular structures.	Cartilage fissuring, joint mice, synovial proliferation, severe biceps lesions. Distinction between clinical and non-clinical OCD lesions.	Not as accurate as newer techniques like arthroscopy, CT, MRI and ultrasound.
Computed Tomography (CT)	Excellent for bony structures and ability to examine complex joint structures. Absence of superimposition. Better soft tissue differentiation than radiography.	Detection of subtle new bone formation and bone lysis. Fragmented coronoid process, IOHC, tarsocrural OCD, the dorsal acetabular rim, extent of primary bone tumours.	May need general anaesthesia. Faster machines allow examination under sedation. Cost of purchasing and maintaining the equipment. Getting used to read axial images. Artefacts.
Magnetic Resonance Imaging (MRI)	Excellent for soft tissue structures. Can evaluate the various components and surrounding structures of the joint.	Bone marrow alterations, bicipital pathology, subchondral lesions in OCD. IOHC. Extent of primary bone tumours.	Needs general anaesthesia. Cost of purchasing and maintaining the equipment. Artefacts. In dogs evaluation of cartilage is difficult (c.f. human joint MRI).
Ultrasound	Non-invasive technique. Good for soft tissue structures like ligaments and joint capsules. Can also pick up new bone formation in the early stages.	Synovial evaluation, as well as tendons and real-time evaluation of hip instability. Articular cartilage can be seen. Fracture healing can be monitored.	Operator dependant. Requires substantial ultrasonographic experience. Not all areas are accessible.

Skeletal scintigraphy is a commonly performed imaging procedure in veterinary medicine mostly in large animal orthopaedics. Whereas conventional techniques like radiography are excellent methods to investigate morphologic changes in bones, radionuclide techniques provide information regarding the metabolic function of the skeleton. The advantages of skeletal scintigraphy are its high sensitivity for detecting early disease and the ease of surveying the entire skeleton. Scintigraphy is a useful technique to localise the cause of obscure lameness or in case of uncertain radiographic findings. Although it is very sensitive, it is not very specific. Radiography, on the other hand, is less sensitive but more specific. Also the spatial

resolution offered by scintigraphy is not well enough to specify anatomic structures. The main drawback to joint imaging using 99m Tc-labeled phosphates is the normal uptake at the end of long bones, especially in immature animals. In some instances it is difficult to determine whether a difference in counts between two joints represents a meaningful finding. Comparison of bilateral images, acquired for the same time, and quantitative analysis of joint images by computer can provide diagnostic guidelines.

Plain radiographs predominantly show the bony structures and only provide minimal information on the other joint structures. In some shoulder OCD cases an impression of the articular cartilage can be obtained when the vacuum phenomenon is present, a finding to be observed in about 20% of the cases. Indirect information on articular soft tissues structures can be present in case of calcification within these structures, mostly a sign of degeneration but can also sometimes be an incidental finding. Sometimes the delineation of the attachment of tendinous structures can be irregular as can be observed in case of some biceps problems. Also using stress radiographs an indirect evidence of articular ligament rupture can be obtained, the most obvious example being a cranial cruciate ligament rupture shown by tibial compression radiographs of the affected knee joint. In people and horses joint space narrowing has been a well-accepted indicator of articular cartilage degeneration and is considered as a cardinal radiographic feature of disease. In small animals the loss of joint space is not a reliable sign as the radiographs are taken non-weight-bearing. A thorough knowledge of the radiographic anatomy including species/breed specific variations, age dependent changes, anatomical variants and radiological skill are as important as the radiographic technique. Characterisation of bone lesions not only includes the description of the abnormality, but also the distribution and localisation in the skeleton, localisation in a specific bone. The final differential diagnosis will develop from the radiological findings, the ID of patient and clinical signs.

Positive contrast arthrography is seldom used in small animal orthopaedics but is an interesting and simple technique for imaging shoulder problems in the dog. In shoulder osteochondrosis (OC) it helps to assess whether a non-mineralized cartilage flap is present with an accuracy of 80% and this finding helps to determine whether a dog should be treated conservatively or surgically. It can be used to visualise joint mice and can also help in the diagnosis of bicipital tendon problems.

Interpretation criteria for skeletal radiographs

Radiographic abnormality
- alteration of architecture (size, shape, border) and proportion, of opacity and structure (osteoporosis/atrophy, osteolysis, osteosclerosis, osteopetrosis)

Intraskeletal distribution
- generalised, (oligo-) polyostotic, monostotic

Localisation
- within the skeleton: bone or bones affected
- within the bone longitudinal: proximal or distal epiphysis, physis (growth plate), metaphysis, and/or diaphysis
- cross sectional: bone marrow, endosteum, compact bone, periosteum, soft tissues
- proximity of nutrient artery

Complications
- e. g. metastases, involvement of other structures/joints

Aggressiveness of a lesion
- well defined margin v. indistinct zone of transition
- active bony proliferation/destruction v. walled-off/encapsulated process

Ultrasound (US) is a potential valuable imaging technique of the musculoskeletal system in small animals. Linear transducers with frequencies higher than 7.5 MHz are used because of their flat application surface and high resolution power. With this technique imaging of joints, especially of the soft tissues (e.g. ligaments, capsule) and of the articular cartilage, can be obtained. Accurate examination of joints requires substantial ultrasonographic experience and a standardised examination procedure. In most of the joints even small amounts of fluid accumulation (hypo- to anechoic) can be easily demonstrated in the area of the joint pouches. Few studies have been reported on the assessment of OC using ultrasonography (US). In human medicine, it is reported that US shows fragmentation of the subchondral bone in patients with OC of the knee. US was also used to evaluate OC lesions of the humeral capitullum. In veterinary medicine, US evaluation of OC lesions in the equine and canine knee is described. The results in a recent study, comparing ultrasonography with radiography, arthrography and arthroscopy, suggest that all radiographically diagnosed subchondral lesions in the humeral head can be visualised by the use of US as a convex deviation of the hyperechoic subchondral bone line with a variable length according to the extent of the lesion. The results also suggest that the presence of second hyperechoic lines at the bottom of the subchondral defect seen on US is a pathognomic sign for the presence of a flap. It was suggested that US might present an alternative to positive contrast arthrography. The US examinations have to be performed under general anaesthesia allowing the necessary maximal endorotation which is otherwise difficult to perform, especially in a painful shoulder. Studies to determine the value of US in tarsocrural OC are undertaken as well and are somewhat promising. In the stifle joint it is possible to evaluate an old rupture of the cranial cruciate ligament (hyperechoic structures at the ends of the ligament), a meniscal tear or degeneration (distinctly inhomogeneous and has a mixed pattern of hyperechoic and hypoechoic areas). US is only of limited use in the diagnosis of a fragmented coronoid process. Pathologic changes of the soft tissues (e.g. tumour) can usually be diagnosed. Joint effusion in the shoulder joint can be diagnosed easily, and appears as a hypo- to anechoic area around the bony components. Bicipital pathology can be easily evaluated. Also Achilles tendon lesions can be evaluated sonographically. Instabilities of the hip joint can be evaluated by dynamic examination. By seeing movement (real-time-system) between the femoral head and the acetabulum it is possible to evaluate laxity of the hip joint.

Computerised tomography (CT) has several advantages over plain radiography. CT enables more detailed and specific morphological diagnosis than radiography. CT greatly facilitates examining complex joint structures like the elbow and tarsus and enables more complete lesion visualisation. Although the spatial resolution of CT images is poorer when compared with classical film-screen radiography, the cross-sectional image display and superior discrimination of tissue attenuation offered by CT enables more complete lesion visualisation. Although the growing availability, reports on its use in small animal orthopaedics are scarce. Ct has been proved to be

superior in the diagnosis of fragmented coronoid process of the elbow joint. Its use in the diagnosis of elbow incongruity has also been reported. In tarsocrural OCD, CT is superior in the diagnosis of lateral ridge involvement. In medial ridge involvement, CT allows to assess the exact localisation, the size and number of the fragments. It helps in decision making when using minimal exposure techniques to treat these lesions. In the treatment of hip dysplasia it can be used to check the status of the dorsal acetabular rim which is an important criterion when triple pelvic osteotomy is considered. The disadvantages are the same as with NMR.

Arthro-CT

A rather recent new application of CT is arthro-CT, the intra-articular application of iodine containing contrast media. Before the application the contrast medium should be diluted till maximum 50 mg of iodine per ml. In severely inflamed joints the admixture of epinephrine can be useful to counteract the rapid absorption of the contrast medium by the inflamed, hyperaemic synovial membrane.
Within the shoulder joint intra-articular structures including the biceps tendon, glenohumeral ligaments and the joint cartilage can be visualised. Application of arthro-CT in the elbow joint is of use in appreciating the status of the articular cartilage in medial compartment syndrome.
Within the stifle joint arthro-CT is helpful in evaluating meniscal damage and in evaluating fragment stability.
In tarsal OCD arthro-CT can be used to evaluate fragment stability.

Magnetic resonance (NMR) is an imaging technique superior for the demonstration of soft tissue lesions. A major advantage of NMR includes its ability to evaluate the various components and surrounding structures of the joint, and not merely the surface visualised by arthroscopy or outlined by contrast material by arthrography. It has been evaluated for detecting OC lesions in the canine humeral head and was found to be useful in assessing the extent of subchondral bone lesions and the severity of inflammatory changes within the subchondral bone. Although articular cartilage discontinuity could be detected, loose flaps were not always demonstrated. In humans it is also used to check stability of osteochondral fragments, which influences the therapeutic regime. Although it is mentioned in the literature that articular cartilage can be visualised, this seems to be difficult in young dogs. The distinction between cartilage and synovial fluid is not obvious. Also the intra-articular administration of Gadolinium-containing agents is not helpful. In the detection of FCP in the elbow joint, the technique can be very helpful in detecting non-mineralised cartilaginous fragments not to be seen on CT. The disadvantage of NMR is the need for general anaesthesia and the cost for maintaining the equipment.

Arthroscopy is an excellent technique to visualise articular structures not visible on radiographs. The magnification factor of the arthroscope allows the inspection in detail of articular cartilage, the synovial membrane and intra-articular ligaments and structures. Arthroscopically guided biopsies of these different structures are also possible. Another advantage is that diagnosis and treatment can be combined especially in OCD lesions. It is very useful in the diagnosis of LPC even when the radiographic and CT findings are negative. Elbow incongruity can be appreciated arthroscopically as well. It is of great help in the diagnosis of bicipital pathology and other shoulder lameness. In the diagnosis of degenerative joint disease the lesions can be detected before they show on radiographs. In cases of arthrotic joints it can

replace an exploratory arthrotomy. The drawbacks of arthroscopy are the rather steep learning curve and the relatively high cost of the equipment.

As a **conclusion** one could state that although a variety of imaging techniques is available nowadays, one should always consider if the results of the used imaging examination (or examinations) will influence the treatment of the patient and, if so, what is the most direct (ie cost effective) way to obtain these results. As in man, the question of over consumption of high technologic imaging modalities can be raised in animals as well.

Further reading:

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